CLAIMS

1. An acoustic wave switch comprising:

a substrate with at least one acoustic cavity formed therein such that the mass per unit area of the acoustic cavity is greater than the mass per unit area of the substrate adjacent the cavity and a surface of the acoustic cavity forming a touch surface for actuating the switch; and

an acoustic wave transducer mounted on the acoustic wave cavity, the transducer generating an acoustic wave that is substantially trapped in the acoustic cavity, wherein a touch on the touch surface of the cavity produces a detectable change in the impedance of the transducer.

2. An acoustic wave switch as recited in claim 1 wherein the acoustic wave generated in the substrate propagates in a direction perpendicular to the thickness of the substrate.

3. An acoustic wave switch as recited in claim 1 wherein the acoustic wave generated in the substrate is a shear wave.

4. An acoustic wave switch as recited in claim 3 wherein said transducer is a thickness shear wave piezoelectric transducer.

5. An acoustic wave switch as recited in claim 1 wherein a ratio of a length of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

6. An acoustic wave switch as recited in claim 1 wherein a ratio of a width of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

7. An acoustic wave switch as recited in claim 1 wherein the transducer is mounted on the acoustic cavity surface along a center line thereof.

8. An acoustic wave switch as recited in claim 1 wherein the transducer is mounted on a raised surface of the substrate defining the acoustic cavity.

9. An acoustic wave switch as recited in claim 1 wherein the transducer is mounted on a surface of the cavity opposite a raised surface of the substrate defining the acoustic cavity.

10. An acoustic wave switch as recited in claim 1 wherein at least a portion of the acoustic cavity is an integral part of the substrate.

11. An acoustic wave switch as recited in claim 1 wherein the substrate is formed of a metal, a glass, a ceramic, or plastic material.

12. An acoustic wave switch as recited in claim 1 wherein the position of the switch is identified by a depression formed in the substrate surface.

13. An acoustic wave switch as recited in claim 12 wherein the depression extends beyond the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

14. An acoustic wave switch as recited in claim 1 wherein the touch surface of the acoustic cavity is identified by a second raised surface located opposite the raised surface defining the acoustic cavity.

15. An acoustic wave switch as recited in claim 14 wherein the raised region extends beyond the edge of the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

16. An acoustic wave switch as recited in claim 1 including a deformable dome positioned over the touch surface to provide audible and/or tactile feedback that the switch has been actuated, the deformable dome including on an inner surface thereof an acoustic wave absorbing material that contacts the touch surface of the acoustic cavity when the dome is deformed to actuate the switch.

17. An acoustic wave switch comprising:

a substrate with a raised surface defining an acoustic cavity such that a thickness of the cavity is greater than a thickness of the substrate in an area adjacent the cavity;

an acoustic wave transducer mounted on a surface of the acoustic cavity, the transducer generating an acoustic wave in the substrate that is substantially trapped in the acoustic cavity;

a circuit coupled to the transducer and responsive to a change in a characteristic thereof to detect a touch on a touch surface of the acoustic cavity.

18. An acoustic wave switch as recited in claim 17 wherein the acoustic wave generated in the substrate propagates in a direction perpendicular to the thickness of the substrate.

19. An acoustic wave switch as recited in claim 17 wherein the acoustic wave generated in the substrate is a shear wave.

20. An acoustic wave switch as recited in claim 19 wherein said transducer is a thickness shear wave piezoelectric transducer.

21. An acoustic wave switch as recited in claim 17 wherein a ratio of a length of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

22. An acoustic wave switch as recited in claim 17 wherein a ratio of a width of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

23. An acoustic wave switch as recited in claim 17 wherein the transducer is mounted on the acoustic cavity surface along a center line thereof.

24. An acoustic wave switch as recited in claim 17 wherein the transducer is mounted on the raised surface of the substrate defining the acoustic cavity.

25. An acoustic wave switch as recited in claim 17 wherein the transducer is mounted on a surface of the cavity opposite the raised surface of the substrate.

26. An acoustic wave switch as recited in claim 17 wherein said raised surface defining the acoustic cavity is formed by mechanically machining the substrate.

27. An acoustic wave switch as recited in claim 17 wherein said raised surface defining the acoustic cavity is formed by chemically processing the substrate.

28. An acoustic wave switch as recited in claim 17 wherein the raised surface defining the acoustic cavity is formed by adhering at least one material to the substrate to increase the mass of the substrate in the area of the acoustic cavity.

29. An acoustic wave switch as recited in claim 28 wherein the raised surface is formed by plating the material on the substrate.

30. An acoustic wave switch as recited in claim 28 wherein the raised surface is formed by thick film screening of material on the substrate.

31. An acoustic wave switch as recited in claim 28 wherein the raised surface is formed by adhering a decal on the substrate.

32. An acoustic wave switch as recited in claim 28 wherein the raised surface is formed by firing a material onto the substrate.

33. An acoustic wave switch as recited in claim 28 wherein the material forming the raised surface is different from a material forming the substrate.

34. An acoustic wave switch as recited in claim 17 wherein at least a portion of the acoustic cavity is an integral part of the substrate.

35. An acoustic wave switch as recited in claim 17 wherein the substrate is formed of a metal, a glass, a ceramic, or plastic material.

36. An acoustic wave switch as recited in claim 1 wherein the substrate is transparent and the raised surface is formed by adhering a non-transparent material to the substrate.

37. An acoustic wave switch as recited in claim 1 wherein the circuit detects a change in impedance of the transducer indicating that the touch surface of the acoustic cavity has been touched.

38. An acoustic wave switch as recited in claim 37 wherein said circuit is an oscillator circuit that oscillates in the absence of a touch

on the touch surface of the acoustic cavity and in response to a change in the impedance of the transducer indicating a touch on the touch surface of the acoustic cavity, the circuit stops oscillating.

39. An acoustic wave switch as recited in claim 17 wherein the position of the switch is identified by a depression formed in the substrate surface.

40. An acoustic wave switch as recited in claim 39 wherein the depression extends beyond the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

41. An acoustic wave switch as recited in claim 17 wherein the touch surface of the acoustic cavity is identified by a second raised surface located opposite the raised surface defining the acoustic cavity.

42. An acoustic wave switch as recited in claim 41 wherein the second raised surface extends beyond the edge of the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

43. An acoustic wave switch as recited in claim 17 including a deformable dome positioned over the touch surface to provide audible and/or tactile feedback that the switch has been actuated, the deformable dome including on an inner surface thereof an acoustic wave absorbing material that contacts the touch surface of the acoustic cavity when the dome is deformed to actuate the switch.

44. An acoustic wave switch comprising:

a substrate;

a mesa formed on the substrate, said mesa defining an acoustic cavity formed of the mesa and the portion of the substrate below the mesa;

a transducer mounted on a surface of the acoustic cavity, the transducer generating an acoustic wave that is substantially trapped in the acoustic cavity;

a circuit coupled to the transducer to detect a touch on a surface of the acoustic cavity.

45. An acoustic wave switch as recited in claim 44 wherein the acoustic wave generated in the substrate propagates in a direction perpendicular to the thickness of the substrate.

46. An acoustic wave switch as recited in claim 44 wherein the acoustic wave generated in the substrate is a shear wave.

47. An acoustic wave switch as recited in claim 46 wherein said transducer is a thickness shear wave piezoelectric transducer.

48. An acoustic wave switch as recited in claim 44 wherein a ratio of a length of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

49. An acoustic wave switch as recited in claim 44 wherein a ratio of a width of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

50. An acoustic wave switch as recited in claim 44 wherein the transducer is mounted on the acoustic cavity surface along a center line thereof.

51. An acoustic wave switch as recited in claim 44 wherein the transducer is mounted onto the mesa of the substrate defining the acoustic cavity.

52. An acoustic wave switch as recited in claim 44 wherein the transducer is mounted on a surface of the cavity opposite to the mesa of the substrate defining the acoustic cavity.

53. An acoustic wave switch as recited in claim 44 wherein said mesa defining the acoustic cavity is formed by mechanically machining the substrate.

54. An acoustic wave switch as recited in claim 44 wherein said mesa defining the acoustic cavity is formed by chemically processing the substrate.

55. An acoustic wave switch as recited in claim 28 wherein the mesa defining the acoustic cavity is formed by adhering at least one

material to the substrate to increase the mass of the substrate in the area of the acoustic cavity.

56. An acoustic wave switch as recited in claim 44 wherein the mesa is formed by plating the material on the substrate.

57. An acoustic wave switch as recited in claim 44 wherein the mesa is formed by thick film screening of material on the substrate.

58. An acoustic wave switch as recited in claim 44 wherein the mesa is formed by adhering a decal on the substrate.

59. An acoustic wave switch as recited in claim 44 wherein the mesa is formed by firing a material onto the substrate.

60. An acoustic wave switch as recited in claim 44 wherein the material forming the mesa is different from a material forming the substrate.

61. An acoustic wave switch as recited in claim 44 wherein at least a portion of the acoustic cavity is an integral part of the substrate.

62. An acoustic wave switch as recited in claim 44 wherein the substrate is formed of a metal, a glass, a ceramic, or plastic material.

63. An acoustic wave switch as recited in claim 44 wherein the substrate is transparent and the mesa is formed by adhering a non-transparent material to the substrate.

64. An acoustic wave switch as recited in claim 44 wherein the circuit detects a change in impedance of the transducer indicating that the touch surface of the acoustic cavity has been touched.

65. An acoustic wave switch as recited in claim 44 wherein said circuit is an oscillator circuit that oscillates in the absence of a touch on the touch surface of the acoustic cavity and in response to a change in the impedance of the transducer indicating a touch on the touch surface of the acoustic cavity, the circuit stops oscillating.

66. An acoustic wave switch as recited in claim 44 wherein the position of the switch is identified by a depression formed in the substrate surface.

67. An acoustic wave switch as recited in claim 66 wherein the depression extends beyond the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

68. An acoustic wave switch as recited in claim 44 wherein the touch surface of the acoustic cavity is identified by a raised surface located opposite the mesa.

69. An acoustic wave switch as recited in claim 68 wherein the raised surface extends beyond the edge of the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

70. An acoustic wave switch as recited in claim 44 including a deformable dome positioned over the touch surface to provide audible and/or tactile feedback that the switch has been actuated, the deformable dome including on an inner surface thereof an acoustic wave absorbing material that contacts the touch surface of the acoustic cavity when the dome is deformed to actuate the switch.

71. A method of generating a shear wave without the zeroth order harmonic mode for an acoustic wave touch sensor comprising:

providing a substrate having a touch surface perpendicular to the thickness of the substrate;

bonding a shear wave transducer to a surface of the substrate that is perpendicular to the thickness of the substrate; and

applying an electrical signal to at least one surface of the transducer that is parallel to the touch surface of the substrate.

72. An acoustic wave switch comprising:

a substrate with at least one acoustic cavity formed therein such that the mass per unit area of the acoustic cavity is greater than the mass per unit area of the substrate adjacent the cavity and a surface of the acoustic cavity forming a touch surface for actuating the switch;

an acoustic wave transducer mounted on the acoustic wave cavity, the transducer generating an acoustic wave that is substantially trapped in the acoustic cavity; and

a circuit coupled to the transducer and responsive to a change in an impedance of the transducer of at least a predetermined amount to generate a signal indicating an actuation of the acoustic switch.

73. An acoustic wave switch as recited in claim 72 wherein said circuit is an oscillator circuit that oscillates in the absence of a touch

on the touch surface of the acoustic cavity and in response to a change in the impedance of the transducer indicating a touch on the touch surface of the acoustic cavity, the circuit stops oscillating.

74. An acoustic wave switch panel comprising:

a substrate with a plurality of acoustic wave cavities formed therein, each acoustic wave cavity forming a portion of an individual switch and each acoustic cavity having a mass per unit area that is greater than the mass per unit area of the substrate adjacent the cavity and having a touch surface for actuating the respective switch; and

a plurality of acoustic wave transducers, each acoustic wave cavity having an acoustic wave transducer mounted thereon to generate an acoustic wave that is substantially trapped in the acoustic cavity, wherein a touch on a touch surface of an acoustic wave cavity produces a detectable change in the impedance of the transducer.

75. An acoustic wave switch panel as recited in claim 74 including a multiplexer to sequentially couple each of said transducers to a circuit responsive to a change in an impedance of the transducer coupled thereto to generate a signal indicating an actuation of the switch formed in part by the acoustic cavity on which the transducer is mounted.

76. An acoustic wave switch panel as recited in claim 75 wherein each transducer generates a shear wave having a harmonic mode of $n \geq 1$.

77. An acoustic wave switch panel as recited in claim 75 wherein each of said acoustic cavities has a ratio of a length of the cavity

to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

78. An acoustic wave switch panel as recited in claim 75 wherein each of said acoustic cavities has a ratio of a width of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

79. An acoustic wave switch panel as recited in claim 75 wherein each of the transducers is mounted along a center line of the acoustic cavity.

80. An acoustic wave switch panel as recited in claim 75 wherein at least a portion of each of the acoustic cavities is an integral part of the substrate.

81. An acoustic wave switch panel as recited in claim 75 wherein the substrate is formed of a metal, a glass, a ceramic or a plastic.

82. An acoustic wave switch as recited in claim 75 wherein the position of each of the switches is identified by a depression formed in the substrate surface.

83. An acoustic wave switch as recited in claim 82 wherein each of the depressions extends beyond the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

84. An acoustic wave switch as recited in claim 75 wherein the touch surface of an acoustic cavity is identified by a raised surface.

85. An acoustic wave switch as recited in claim 84 wherein the raised surface extends beyond the edge of the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

86. An acoustic wave switch as recited in claim 75 including a deformable dome positioned over each of the touch surfaces to provide audible and/or tactile feedback that the switch has been actuated, the deformable dome including on an inner surface thereof an acoustic wave absorbing material that contacts the touch surface of the acoustic cavity when the dome is deformed to actuate the switch.

87. An acoustic wave switch panel comprising:

a substrate;

a plurality of mesas formed on the substrate, each of said mesas being associated with an individual switch and defining an acoustic

cavity formed of the mesa and the portion of the substrate below the mesa;

a plurality of transducers each mounted on a surface of a respective acoustic cavity that is substantially trapped in the acoustic cavity wherein a touch on a touch surface of an acoustic cavity produces a detectable change in the impedance of the transducer.

88. An acoustic wave switch panel as recited in claim 87 wherein each mesa height is less than or equal to approximately 10% of the thickness of the acoustic cavity.

89. An acoustic wave switch panel as recited in claim 88 wherein each mesa height is less than or equal to approximately 5% of the thickness of the acoustic cavity.

90. An acoustic wave switch panel as recited in claim 87 wherein each transducer generates a shear wave having a harmonic mode of $n \geq 1$.

91. An acoustic wave switch panel as recited in claim 87 wherein each of said acoustic cavities has a ratio of a length of the cavity to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

92. An acoustic wave switch panel as recited in claim 87 wherein each of said acoustic cavities has a ratio of a width of the cavity

to the thickness of the cavity is less than or equal to $\frac{1}{n}\sqrt{\frac{2b_s}{h_c}}$ where n is an order of a harmonic mode of the generated acoustic wave, b_s is the thickness of the substrate in the area adjacent the cavity and h_c is the difference between the thickness of the cavity and the thickness of the substrate.

93. An acoustic wave switch panel as recited in claim 87 wherein each of the transducers is mounted along a center line of the acoustic cavity.

94. An acoustic wave switch panel as recited in claim 87 wherein at least a portion of each of the acoustic cavities is an integral part of the substrate.

95. An acoustic wave switch panel as recited in claim 87 wherein the substrate is formed of a metal, a glass, a ceramic or a plastic.

96. An acoustic wave switch as recited in claim 87 wherein the position of each of the switches is identified by a depression formed in the substrate surface.

97. An acoustic wave switch as recited in claim 96 wherein each of the depressions extends beyond the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

98. An acoustic wave switch as recited in claim 87 wherein the touch surface of an acoustic cavity is identified by a second raised surface located opposite the raised surface defining the acoustic cavity.

99. An acoustic wave switch as recited in claim 98 wherein the raised region extends beyond the edge of the cavity by an amount that is greater than or equal to approximately 0.6 times the thickness of the cavity divided by the order of the harmonic mode of the generated acoustic wave.

100. An acoustic wave switch as recited in claim 87 including a deformable dome positioned over each of the touch surfaces to provide audible and/or tactile feedback that the switch has been actuated, the deformable dome including on an inner surface thereof an acoustic wave absorbing material that contacts the touch surface of the acoustic cavity when the dome is deformed to actuate the switch.

101. An acoustic wave switch as recited in claim 87 wherein each mesa defining the acoustic cavity is formed by mechanically machining the substrate.

102. An acoustic wave switch as recited in claim 87 wherein each mesa defining the acoustic cavity is formed by chemically processing the substrate.

103. An acoustic wave switch as recited in claim 87 wherein each mesa defining the acoustic cavity is formed by adhering at least one material to the substrate to increase the mass of the substrate in the area of the acoustic cavity.

104. An acoustic wave switch as recited in claim 87 wherein each mesa is formed by plating the material on the substrate.

105. An acoustic wave switch as recited in claim 87 wherein each mesa is formed by thick film screening of material on the substrate.

106. An acoustic wave switch as recited in claim 87 wherein each mesa is formed by adhering a decal on the substrate.

107. An acoustic wave switch as recited in claim 87 wherein each mesa is formed by firing a material onto the substrate.

108. An acoustic wave switch as recited in claim 87 wherein the material forming each mesa is different from a material forming the substrate.

109. An acoustic wave switch as recited in claim 87 wherein the substrate is transparent and the mesa is formed by adhering a non-transparent material to the substrate.

110. An acoustic wave switch panel comprising:

a substrate;

a plurality of mesas formed on the substrate, each of said mesas being associated with an individual switch and defining an acoustic cavity formed of the mesa and the portion of the substrate below the mesa;

a plurality of shear wave transducers, each transducer being mounted along a center line of a respective acoustic cavity on a surface thereof that is opposite a touch surface of the acoustic cavity wherein a

touch on a touch surface of an acoustic cavity produces a detectable change in the impedance of the transducer.

111. An acoustic wave switch comprising:

a substrate;

a mesa formed on the substrate;

a shear wave transducer mounted on the mesa or a surface of the substrate opposite the mesa wherein a touch on a touch surface of the substrate opposite the transducer produces a detectable change in the impedance of the transducer.

112. An acoustic wave switch comprising:

a substrate;

a mesa formed on the substrate defining an acoustic wave cavity; and

a driver generating an acoustic wave in the acoustic wave cavity wherein a touch on a touch surface of the acoustic wave cavity produces a detectable change in the acoustic wave in the cavity.

113. An acoustic wave switch comprising:

a substrate;

a moat formed in the substrate defining a mesa surrounded by the moat, the mesa defining an acoustic wave cavity; and

a driver generating an acoustic wave in the acoustic wave cavity wherein a touch on a touch surface of the acoustic wave cavity produces a detectable change in the acoustic wave in the cavity.

114. An acoustic wave switch comprising:

a substrate;

a circular mesa formed on the substrate defining an acoustic wave cavity; and

a driver generating an acoustic wave in the acoustic wave cavity wherein a touch on a touch surface of the acoustic wave cavity produces a detectable change in the acoustic wave in the cavity.

115. An acoustic wave switch as recited in claim 114 wherein the driver is a shear wave transducer mounted on a diameter of the acoustic wave cavity.

116. An acoustic wave switch as recited in claim 115 wherein the transducer has a length less than the diameter of the circular mesa.

117. An acoustic wave switch as recited in claim 114 wherein the circular mesa includes an area of the substrate surrounded by a moat formed in the substrate.

118. An acoustic wave switch comprising:

a substrate;

a dome shaped mesa formed on the substrate defining an acoustic wave cavity; and

a driver generating an acoustic wave in the acoustic wave cavity wherein a touch on a touch surface of the acoustic wave cavity produces a detectable change in the acoustic wave in the cavity.

119. An acoustic wave switch as recited in claim 118 wherein the driver is a shear wave transducer mounted on a surface of the substrate opposite the dome shaped mesa.

120. An acoustic wave switch as recited in claim 118 wherein the dome shaped mesa is surrounded by a moat in the substrate.